

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**



Europäisches Patentamt
Europ an Patent Office
Office européen des brevets

Publication number:

0 126 626
A2

EUROPEAN PATENT APPLICATION

Application number: 84303358.4

Int. Cl.³: H 01 Q 3/26

Date of filing: 17.05.84

Priority: 23.05.83 US 497349
23.05.83 US 497350

Applicant: HAZELTINE CORPORATION, 500 Commack Road, Commack New York 11725 (US)

Date of publication of application: 28.11.84
Bulletin 84/48

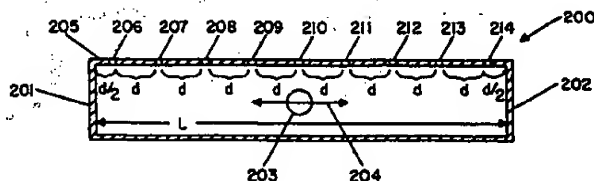
Inventor: Frazita, Richard F., 12 Skunks Hollow Road, St. James New York 11780 (US)
Inventor: Lopez, Alfred R., 4 Sarina Drive, Commack New York 11725 (US)

Designated Contracting States: DE FR GB IT NL SE

Representative: Wood, Anthony Charles et al, c/o MICHAEL BURNSIDE & PARTNERS 2 Serjeants' Inn Fleet Street, London EC4Y 1HL (GB)

Resonant waveguide aperture manifold.

A waveguide manifold (200) for monitoring the operation of an array antenna (1). The waveguide is centered (203) and has reflecting terminations (201, 202) at either end. The waveguide output is matched to the waveguide as if non-reflecting terminations were at either end of the waveguide. The waveguide input is a plurality of groups of slots (206-214) wherein adjacent slots in each group (A, B, C, D) have alternating polarity and adjacent groups may have alternating phase. A standing wave created in the waveguide has a plurality of cells of alternating phase (Fig. 11). Each slot is located within one of the resonating standing wave cells. The resulting manifold beam forming characteristic will be temperature and frequency independent over a practical range.



EP 0 126 626 A2

Docket R4287/78.07

FRA:mpk

1 RESONANT WAVEGUIDE APERTURE MANIFOLD

2 The invention relates generally to
3 phase-stable manifolds and, in particular, a resonant
4 waveguide for monitoring a scanning beam antenna
5 essentially independent of temperature and frequency
6 over a practical range and for monitoring a scanning
7 beam antenna at a scan angle which is not aligned with
8 the boresight direction of the antenna.

9 Slotted waveguides are sometimes used
10 as aperture manifolds which couple to the radiated
11 signal of a phased-array antenna to monitor its
12 performance. Such waveguide manifolds are used in
13 Microwave Landing System (MLS) ground systems for
14 producing a signal equivalent to a signal viewed by a
15 receiver at a specific angle within the coverage
16 volume of the ground system. Ideally, such waveguide
17 manifolds provide a far-field view of the scanning
18 beam of the ground system and, additionally, measure
19 the antenna insertion phase and amplitude associated
20 with each individual array element.

1 Waveguide manifolds used to monitor
2 elevation and azimuth scanning beams of an MLS ground
3 system have been waveguides which propagate travelling
4 waves and, consequently, the phasing characteristics
5 are frequency and temperature dependent. The result
6 is that the scan angle of the beam monitored at the
7 waveguide output is also temperature and frequency
8 dependent. Furthermore, for monitoring MLS azimuth
9 scanning, a travelling wave manifold does not
10 inherently monitor the zero degree course over the
11 MLS operating frequency bandwidth. This is because
12 the beam pointing characteristic of a travelling
13 wave manifold is frequency and temperature dependent.
14 It is an object of this invention to
15 provide a resonant waveguide aperture manifold that
16 forms a beam at a scan angle that is independent
17 of temperature and frequency.
18 The apparatus according to the invention
19 comprises a transmission line for directing
20 electromagnetic energy in a predetermined frequency
21 range. Associated with the line are elements such
22 as coupling slots or holes. The line may be
23 associated with groups of elements such
24 as coupling slots or holes wherein adjacent
25 groups have different phase. Each group has N

1 elements wherein adjacent elements have different
2 phase, N being a positive integer greater than one.

3 A transducer is associated with the line
4 for converting energy having a frequency within the
5 predetermined frequency range into an electrical
6 signal having a corresponding frequency and vice
7 versa. The transducer has an impedance which is
8 matched to the line as if the line had non-reflecting
9 terminations coupled to the first and second ends
10 thereof. First means creates a short circuit at the
11 first end of the line and second means creates a short
12 circuit at the second end of the line.

13 For a better understanding of the present
14 invention, together with other and further objects,
15 reference is made to the following description, taken
16 in conjunction with the accompanying drawings, and its
17 scope will be pointed out in the appended claims.

18 Figure 1 is a longitudinal cross-sectional
19 view of a travelling waveguide according to the prior
20 art.

21 Figure 2 is a simplified block diagram
22 illustrating one use of an aperture manifold as described
23 in copending European Application No.83.304471.2 filed
24 3rd August 1983 for Scanning Antenna With
25 Automatic Beam Stabilization, incorporated herein by
26 reference.

1 Figure 3 is a longitudinal cross-sectional
2 view of a resonant waveguide according to the
3 invention.

4 Figure 4A is a perspective view of one side
5 of a resonant waveguide according to the invention
6 showing the slots therein.

7 Figure 4B is a perspective view of one side
8 of an asymmetric resonant waveguide according to
9 the invention showing the adjacent groups of
10 slots of alternating phase wherein each group
11 has adjacent slots of alternating phase.

12 Figure 5 is a transverse cross-sectional
13 view of one resonant waveguide according to the
14 invention illustrating its rectangular configuration.

15 Figure 6 is a transverse cross-sectional
16 view of another resonant waveguide according to the
17 invention illustrating its ridged rectangular
18 configuration.

19 Figure 7 is an amplitude diagram of an
20 incident wave propagating within a waveguide according
21 to the invention.

22 Figure 8 is a phase diagram of an incident
23 wave propagating within a waveguide according to the
24 invention.

1 Figure 9 is an amplitude diagram of a
2 reflected wave propagating within a waveguide
3 according to the invention.

4 Figure 10 is a phase diagram of a
5 reflected wave propagating within a waveguide
6 according to the invention.

7 Figure 11 is a diagram of the standing
8 wave generated within a resonant waveguide according
9 to the invention.

10 Figure 12 is one illustration of the
11 resonant waveguide according to the invention coupled
12 by means of slots to the radiating waveguide column of
13 an MLS azimuth antenna.

14 Figure 13 is another illustration of a
15 resonant waveguide according to the invention coupled
16 by means of holes to the radiating waveguide column of
17 an MLS azimuth antenna.

18 Figure 14 is an illustration of a resonant
19 waveguide according to the invention coupled by means
20 of slots to the radiating waveguide column of an MLS
21 elevation antenna.

22 As shown in figure 1, a prior art
23 travelling wave manifold 100 made of conductive
24 material is provided with an output transducer such as
25 connector 101 which receives a wave propagating along

-6-

1 propagation path 102 which is terminated in absorber
2 103 or other non-reflecting terminating means at the
3 far end. Side 104 functions as a short circuit which
4 reflects waves propagating to the left. Side 105 of
5 waveguide 100 is provided with weakly coupled input
6 slots 106, 107, 108, 109, 110, 111, 112 and 113 having
7 spacing d. The phase relationship between adjacent
8 slots 106 and 107 is given by the following formula:

9
$$\phi_{107} = \phi_{106} + \frac{2\pi d}{\lambda_g} \pm \pi$$

10 As shown by the formula, the phase of slot
11 107 (ϕ_{107}) as compared to the phase of slot 106
12 (ϕ_{106}) is dependent upon the spacing d and the
13 waveguide wavelength (λ_g). All other adjacent slots
14 have similar phase relationships. Since spacing d is
15 temperature dependent (conductive material such as
16 copper or aluminum expands or contracts with
17 temperature variations) and the waveguide wavelength
18 λ_g is frequency dependent, travelling wave manifold
19 100 is both frequency and temperature dependent.

20 The monitored beam pointing angle, θ , for
21 the travelling wave manifold having slots of
22 alternating phase is defined as the pointing angle of
23 a beam provided at the manifold output connector as a

1 result of excitations imparted at the manifold slots.

2 By reciprocity, it may be defined as the conjugate of

3 the pointing angle of a beam radiated by the manifold

4 output slots as a result of excitations imparted by

5 the manifold input connector. The monitored beam

6 pointing angle is given by:

7
$$\theta = \arcsin \sqrt{(1 - (\lambda_o f_o / \lambda_{co} f)^2 - \lambda_o f_o / 2df)}$$

8 where

9 λ_o = reference free space wavelength (design center)

10 λ_{co} = waveguide cutoff wavelength

11 f_o = reference frequency

12 f = frequency of excitations

13 This equation gives the explicit relationship

14 between the monitored beam pointing angle, frequency

15 and coupling slot spacing. The invention relates to:

16 (a) microwave landing systems which use wide scanning

17 phased array antenna systems having a sharp cutoff of

18 the element pattern, such as are disclosed by Richard

19 F. Frazita, Alfred R. Lopez and Richard J. Giannini in

20 U.S. Patent No. 4,041,501; and (b) calibration of a

21 system having plural signal carrying channels.

1 Referring to Figure 2, generally such antenna systems
2 include one or more radiating elements forming an
3 array 1 in which the elements are arranged along an
4 array axis and are spaced from each other by a given
5 distance. Each of the elements is coupled to a power
6 divider 8 via a corresponding one of a plurality
7 of phase shifters 9 connected to the elements by
8 distribution network 2. Wave energy signals from
9 signal generator 11 and power divider 8 are
10 supplied to antenna elements 1 by phase
11 shifters 9 such that a proper selection of the
12 relative phase values for phase shifters 9 causes
13 antenna elements 12 to radiate a desired radiation
14 pattern into a selected angular region of space.
15 Variation of the relative phase values of the phase
16 shifters 9 is accomplished by beam steering unit 10
17 via control line 22 and causes the radiated antenna
18 pattern to change direction with respect to angle A in
19 space. Therefore, phase shifters 9 and beam steering
20 unit 10 together form means 2 for scanning a beam
21 radiated by the antenna elements of array 1 as a
22 result of the supplied wave energy signals from
23 generator 11 coupled to the elements of array 1 by
24 power divider 8 and distribution network 2.

1 The properties of a scanning antenna and
2 techniques for selecting design parameters such as
3 aperture length, element spacing and the particular
4 configuration of the distribution network 2 are well
5 known in the prior art. A review of these parameters
6 is completely described in U.S. Patent No. 4,041,501.
7 In order to stabilize the beam pointing
8 angle of the radiated beam, an aperture manifold 4 is
9 associated with the antenna elements of array 1.
10 Manifold 4 may be any means for forming a signal
11 provided by output 12 which represents a beam pointing
12 angle of the radiated beam. Preferably, manifold 4 is
13 a highly phase stable waveguide or manifold, such as
14 the invention, coupled to the array 2 and center-fed
15 to avoid inherent frequency (phase) and temperature
16 effects. Center feeding also eliminates first-order
17 dependence on frequency and absolute temperature
18 variations.
19 As used herein, manifold 4 refers to any
20 type of device for sampling signals including a
21 waveguide, a printed circuit network, a coaxial line
22 network or a power combiner. A phase stable manifold
23 is, by definition, one in which the beam formed by
24 summing of the slot excitations is insensitive to
25 frequency and temperature changes and is used in

1 combination with a phased array in accordance with
2 this invention to detect bias error at a specific
3 angle. Manifold 4 is equivalent in function to a
4 probe located in space at a specific angle with
5 respect to the phased array. A manifold in accordance
6 with the present invention may be a slotted waveguide
7 configured to monitor radiated energy such that there
8 is equal, non-zero phase and equal amplitude at all
9 sample points (i.e. slot locations) of the manifold.

10 The output 12 of manifold 4 is coupled to
11 means 5, associated with means 3, for controlling the
12 scanning of the radiated beam in response to the
13 output 12 of manifold 4.

14 Figure 3 illustrates a resonant waveguide
15 200 according to the invention. Waveguide 200 is
16 provided with a first end 201 terminating in a short
17 circuit such as a conductive sheet of metal
18 perpendicular to the sides of waveguide 200 and a
19 second end 202 terminating in a short circuit.
20 Waveguide 200 is center fed by a transducer which
21 converts an electrical signal into electromagnetic
22 energy and vice versa. Preferably, the transducer is
23 any connector well known in the prior art such as
24 output connector 203 which receive waves propagating
25 in both directions along path 204. Side 205 of

1 waveguide 200 is provided with slots 206, 207, 208,
2 209, 210, 211, 212, 213, and 214 for coupling to a
3 radiating antenna. Figure 4 illustrates a 180°
4 degree phase compensating pattern of the coupling
5 slots which will be described below. Figures 5 and 6
6 illustrate preferred rectangular crossections of
7 waveguide 200.

8 As shown by Figure 7, an incident wave
9 radiated by connector 203 has a constant amplitude
10 A_{inc} along the entire length of waveguide 200. This
11 is because amplitude tapers in the travelling wave
12 caused by the coupling slots is counteracted and
13 eliminated by the resonance of waveguide 200.

14 Due to reciprocity, waveguide 200 may be
15 used in either a transmitting or receiving mode. In
16 the transmitting mode, connector 203 is connected via
17 isolator 215 to a signal source (not shown). The
18 signal is converted by connector 203 to
19 electromagnetic wave energy which propagates along
20 waveguide 200 and is radiated by slots 206-214. In
21 the receiving mode, slots 206-214 are illuminated by
22 electromagnetic wave energy which propagates along
23 waveguide 200 and is converted by connector 203 into
24 an electrical signal. For convenience and according
25 to convention, the invention has been described in a

-12-

1 receiving mode. However, this disclosure and the
2 scope of the claims appended hereto should not be
3 limited to any one mode and should be broadly
4 construed to include both transmitting and/or
5 receiving operations.

6 Figure 8 is an illustration of the
7 incident phase ϕ_{inc} of the wave radiated by
8 connector 203 and illustrates that the phase along
9 waveguide 200 is linearly changing.

10 Since short circuits 201 and 202 reflect
11 the incident waves propagating within waveguide 200,
12 figure 9 illustrates that the amplitude of the
13 reflected wave A_{ref} is constant along the entire
14 length of waveguide 200. Similarly, the phase of the
15 reflected wave ϕ_{ref} propagating within waveguide 200
16 is linearly changing with distance. The result, as
17 illustrated in figure 11, is a standing wave having a
18 plurality of cells of alternating phase of zero
19 degrees and 180 degrees between spacing d of the slots.

20 As shown in Figure 4A, each slot is located
21 within one of the standing wave cells of waveguide 200
22 so that the resulting manifold output will be
23 temperature and frequency independent as long as the
24 variations in temperature and frequency are within the
25 range such that there is one and only one slot or

-13-

1 group of slots located within each standing wave
2 cell. By alternating the direction and thereby the
3 phase of adjacent slots, the resulting manifold output
4 will provide equal phasing to all radiating elements.
5 This aperture manifold provides a beam forming
6 capability which is independent of frequency and
7 temperature since the phase within each standing wave
8 cell is constant. To prevent transmission of the
9 reflected wave back through connector 203, isolator
10 215 is located within the line feeding connector 203.

11 As shown in Figure 4B, each slot is located
12 within one of the standing wave cells of waveguide
13 200. By alternating the direction and thereby the
14 phase of the slots, the resulting manifold output will
15 have equal phase for each coupling slot and will
16 be temperature and frequency independent as long
17 as the variations in temperature and frequency are
18 within the range such that there is one and only one
19 slot or group of slots located within each standing
20 wave cell. By alternating the direction and thereby
21 the phase of each group A, B, C and D of slots ($N=2$)
22 and by alternating direction and thereby the phase of
23 adjacent slots within each group, the resulting
24 manifold output will approximate an 11.25° beam
25 pointing angle. This aperture manifold provides a

-14-

1 beam forming capability which is independent of
2 frequency and temperature since the phase within each
3 standing wave cell is constant. To prevent
4 transmission of the reflected wave back through
5 connector 203, isolator 215 is located within the line
6 feeding connector 203.

7 The monitored beam pointing angle, θ , for
8 resonant manifold 200 according to the invention, over
9 the operational frequency bandwidth, is given by:

10
$$\theta = \arcsin \frac{0.5}{md/\lambda_g}, \quad m = 1, 2, \dots, \infty$$

11 where d/λ_g is the slot spacing in guide wavelengths.
12 Therefore, the phasing of manifold 200 is independent
13 of frequency and coupling slot spacing over the
14 operational frequency bandwidth. In the embodiment
15 illustrated in Figure 4A, $\theta = 0^\circ (m = \infty)$ and the
16 beam radiated is perpendicular to path 204. In the
17 embodiment illustrated in Figure 4B, the beam pointing
18 angle is generally not 0° and the beam radiated by
19 manifold 200 is not perpendicular to path 204 because
20 of the nonequal phasing of the groups of slots. For
21 example, an MLS ground system having a center
22 operating frequency of 5.06GHz (i.e. $\lambda = 2.33$ inches)
23 and a group spacing (d_g) of 5.97" would have a

1 monitored beam pointing angle of 11.25° .

2 However, slots 206-214 may be phased to

3 approximate any beam pointing angle desired. The

4 range of the actual beam pointing angles which the

5 slots of a particular manifold may approximate are

6 limited by the physical configuration of the

7 particular manifold. In any case, therefore, the

8 phasing of manifold 200 is independent of frequency

9 and coupling slot spacing over the operational

10 frequency bandwidth.

11 In order to achieve the results described

12 above, input connector 205 is initially matched to

13 waveguide 200 as if each end of waveguide 200

14 terminated in a non-reflecting absorber as shown in

15 the prior art illustrated in figure 1. Such a matched

16 connector 205 is employed with waveguide 200

17 terminating in short circuits as illustrated in figure

18 2 thereby resulting in the resonant standing wave as

19 shown in figure 9.

20 To achieve the in-phase condition of the

21 adjacent coupling slots of waveguide 200, the required

22 waveguide wavelength λ_g is twice the spacing d

23 between coupling slots 206-214. This spacing d is

24 determined by the radiating characteristics of the

25 phased array antenna associated with waveguide 200 and

-16-

1 is typically slightly larger than 1/2 wavelength. For
 2 the Microwave Landing System elevation phased array
 3 antenna, ridge loading as shown in Figure 6 is used to
 4 obtain this result. In particular, opposing ridges
 5 250R and 260R are located within waveguide 200R for
 6 eliminating odd mode resonance which may disturb the
 7 amplitude and phase of the slot excitations.

8 The maximum length, L, of a manifold
 9 according to the invention is limited by the
 10 operational frequency bandwidth of the phased array
 11 antenna with which it is associated. To limit the
 12 beam distortions caused by amplitude taper at the band
 13 edges, length L should not exceed the value given
 14 below:

$$15 \quad L \leq \frac{\lambda_0 f_0}{2(f_{\max} \sqrt{1 - (1 - \lambda_0 f_0 / \lambda_{co} f_{\max})^2} - f_{\min} \sqrt{1 - (1 - \lambda_0 f_0 / \lambda_{co} f_{\min})^2})}$$

16 For the ICAO standard Microwave Landing System
 17 bandwidth, L is given approximately by:

$$18 \quad L \approx \frac{\lambda_g f_0}{2\Delta f}$$

1 where $\Delta f/f_0$ is the fractional design bandwidth plus
2 a margin for fabrication tolerances.
3 For $\Delta f/f_0 = .0165$, $L = 30.3 \lambda_g$. For larger arrays on
4 the order of $60 \lambda_g$, two similar manifolds can be
5 interconnected with equal length stable transmission
6 lines.

7 Figure 12 illustrates waveguide 200R in
8 association with waveguide 300 such as described by
9 U.S. Patent No. 3,903,524, owned by Hazeltine
10 Corporation. Waveguide 300 may be one of a
11 series of parallel waveguides forming the
12 azimuth antenna of a Microwave Landing System (MLS)
13 ground system. Such a ground system requires
14 monitoring to evaluate its performance. In order to
15 provide such monitoring, waveguide 200R functions as a
16 manifold and is associated with each of the parallel
17 waveguides 300. Ridge loading in waveguide 200R in
18 the form of ridges 250R and 260R is used to match the
19 guide wavelength of waveguide 200 to the required
20 spacing of radiating waveguides 300. Specifically,
21 waveguide 300 with polarized radiating slots 301 has a
22 non-polarized opening 302 coupled to slot 208R. Other
23 vertical waveguides would be coupled to slots 206R and
24 207R.

-18-

1 Figure 13 illustrates another MLS ground
2 system coupling configuration having non-polarized
3 holes 506R, 507R and 508R in broad wall 509R of
4 waveguide 500R and having ridge 510R on broad wall
5 511R. The non-polarized holes are coupled to parallel
6 radiating waveguides such as waveguide 300 by
7 polarized slot 303. For this configuration the
8 required 180 degree phase reversals between adjacent
9 coupling holes is incorporated in the design of
10 waveguide 300. Adjacent waveguides 300 have a 180°
11 phase reversal at their input wave launchers i.e. slot
12 303.

13 Figure 14 illustrates another MLS ground
14 system coupling configuration wherein slots 206, 206a,
15 207, 207a, 208, 208a, are coupled to dipole array 400
16 which may function as an MLS elevation antenna.
17 Although this invention has been particularly
18 described with regard to its function as an elevation
19 manifold, it may be used as an azimuth manifold or
20 other array monitor.

CLAIMS

1. Apparatus comprising a transmission line (200) for directing electromagnetic energy in a predetermined frequency range, said line having first and second ends; and elements (206-214) associated with said line; said apparatus characterised by:

(a) a transducer (203) associated with said line for converting energy having a frequency within the predetermined frequency range into an electrical signal having a corresponding frequency and vice versa, said transducer having an impedance which is matched to said line as if said line had substantially non-reflecting terminations coupled to the first and second ends thereof;

(b) a first short circuit (201) at the first end of said line; and

(c) a second short circuit (202) at the second end of said line.

2. Apparatus according to claim 1 wherein adjacent elements (Fig. 4A) have different phases.

3. Apparatus according to claim 1 or claim 2 wherein said transmission line (200) comprises an electrically conductive hollow member and said elements comprise openings (206-214, 506-508) in said member.

4. Apparatus according to claim 3 wherein said electrically conductive hollow member is a linear waveguide of rectangular cross-section (Figures 5

and 6) and said openings comprise a linear array of slots spaced apart by substantially one-half of the waveguide wavelength of said member (Figure 3).

5. Apparatus according to claim 4 wherein said transducer comprises a connector (203) projecting into said member.

6. Apparatus according to claim 5 further including a circuit (215) for isolating from the waveguide any load connected to the connector.

10 7. Apparatus according to any one of claims 4 to 6 wherein said first short circuit (201) comprises a first electrically conductive member substantially perpendicular to the sides of said waveguide and attached to the first end, and said second short
15 circuit comprises a second electrically conductive member substantially perpendicular to the sides of said waveguide and attached to the second end (Figure 3).

8. Apparatus according to any one of claims 1
20 to 7 wherein adjacent elements have opposite phases (Figure 4A).

9. Apparatus according to any one of claims 1 to 8 further including apparatus (250,260) for eliminating odd mode resonance thereby reducing
25 amplitude and phase distortions of the element excitations.

21.

10. Apparatus according to claim 9 wherein said apparatus for eliminating comprises a ridge (250, 260) located within said member.

11. Apparatus according to any one of claims 1 to 10 comprising: groups (A,B,C, D) of elements associated with said line wherein adjacent groups have different phase (Figure 4B), each group having N elements wherein adjacent elements within each group have different phases, where N is a positive even integer greater than one; whereby supplying an electrical signal having a frequency within the predetermined frequency range to the transducer results in the elements radiating a beam which is not perpendicular to the transmission line.

12. Apparatus according to claim 11 wherein said elements are waveguide slots configured to approximate a beam pointing angle of approximately 11.25° (Figure 4B).

13. Apparatus according to claim 11 or claim 12 wherein adjacent groups (AB,BC,CD) of elements have opposite phases and adjacent elements within each group have opposite phases (Figure 4B).

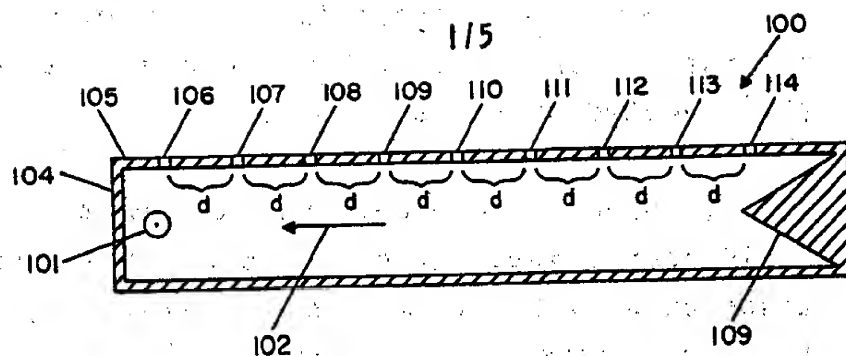


FIG. 1 PRIOR ART

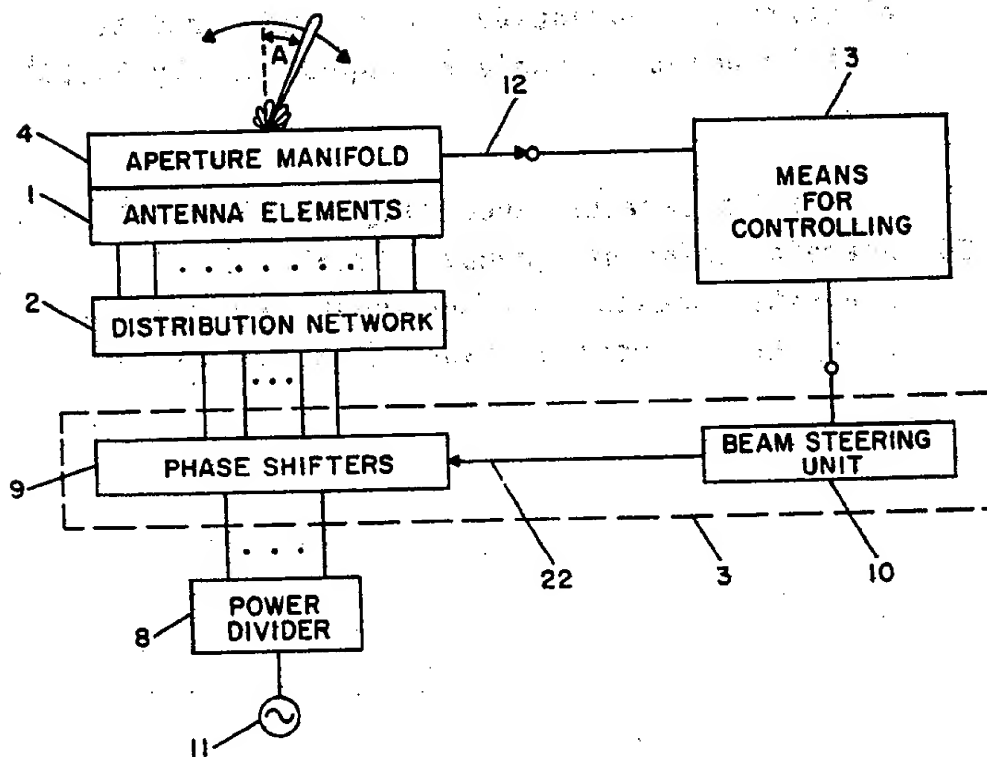


FIG. 2

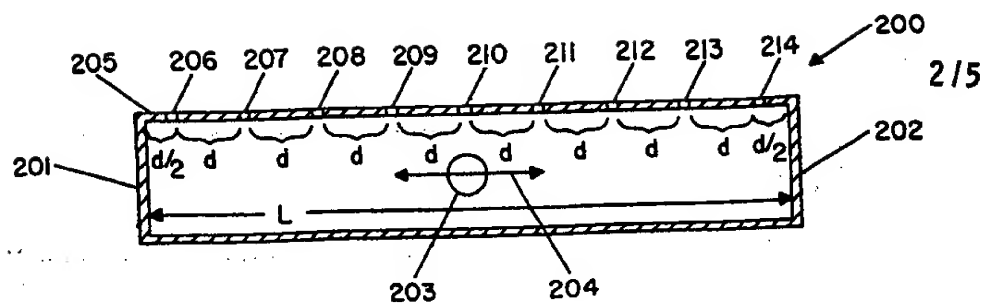


FIG. 3

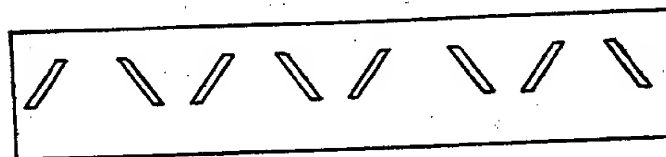


FIG. 4A

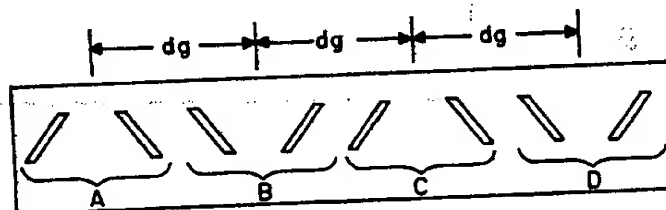


FIG. 4B

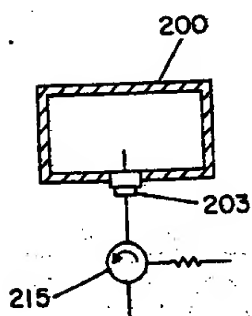


FIG. 5

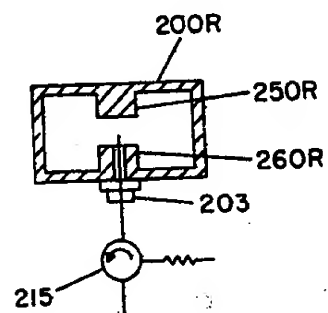


FIG. 6

FIG. 7

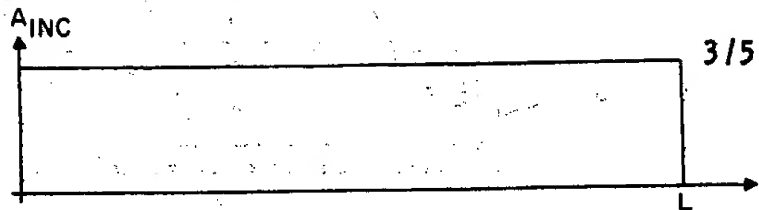


FIG. 8

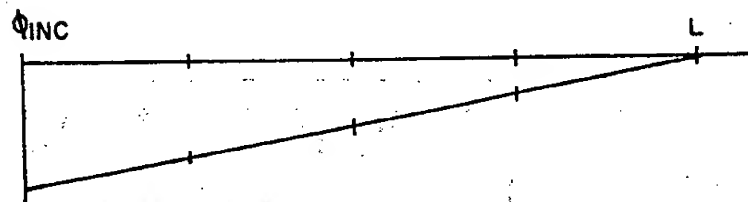


FIG. 9

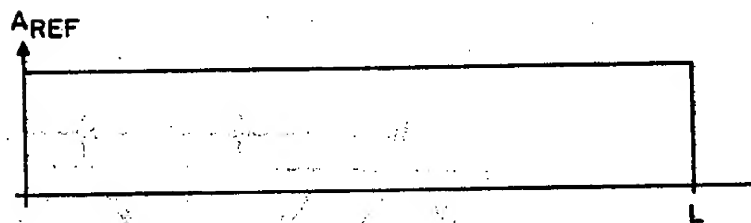


FIG. 10

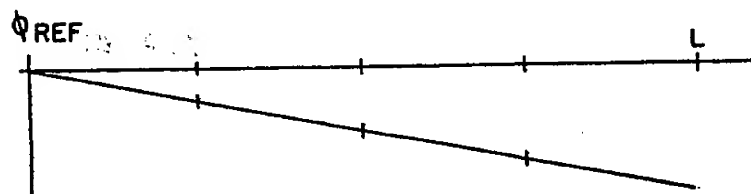
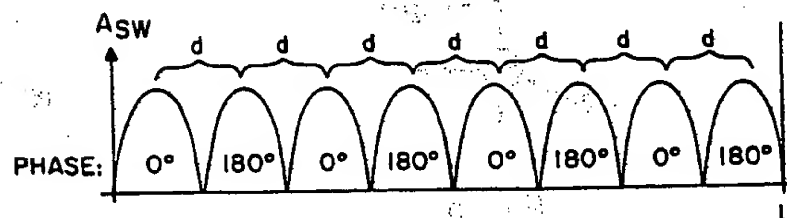


FIG. 11



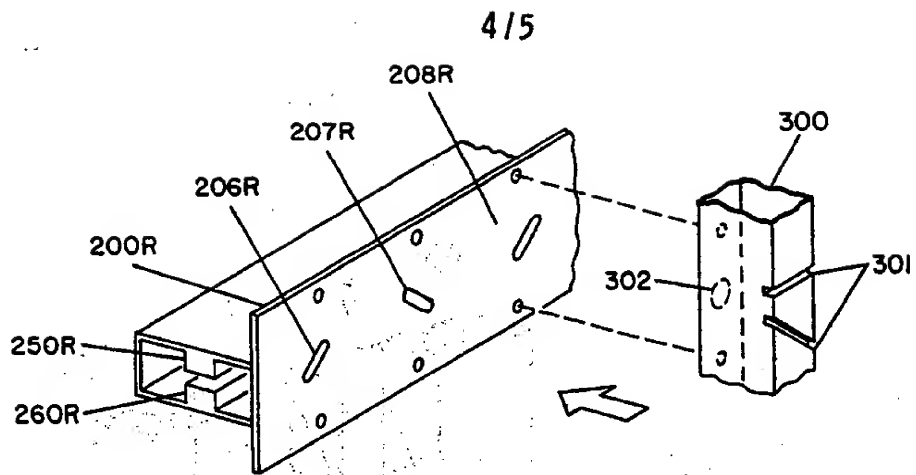


FIG. 12

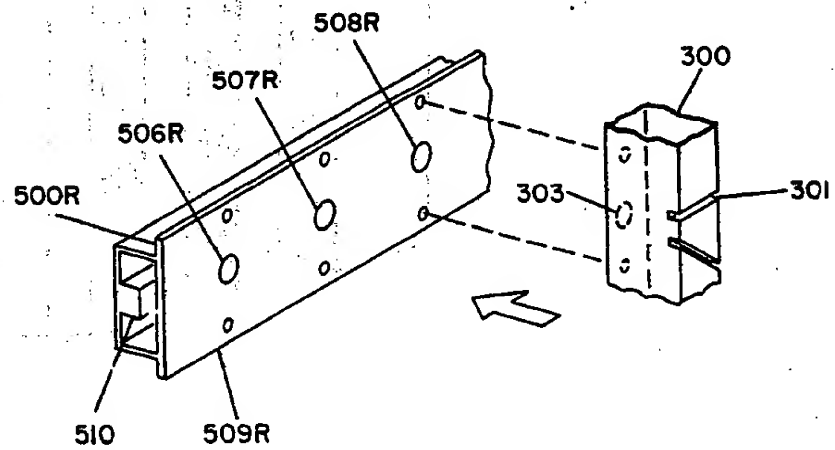


FIG. 13

5/5

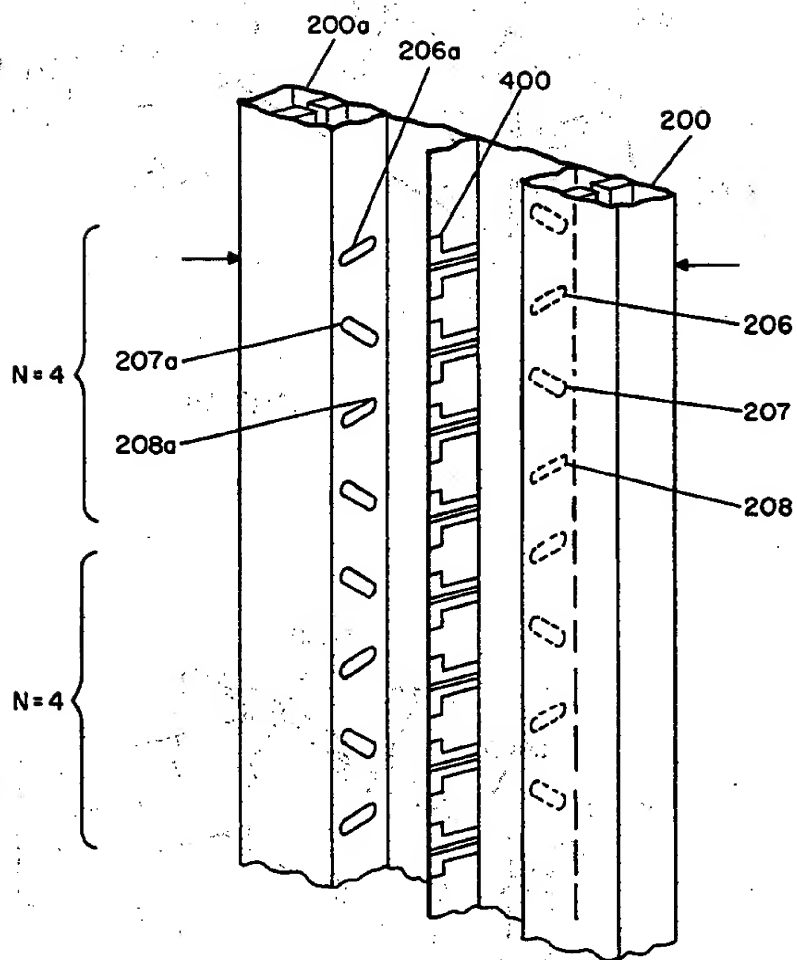


FIG. 14